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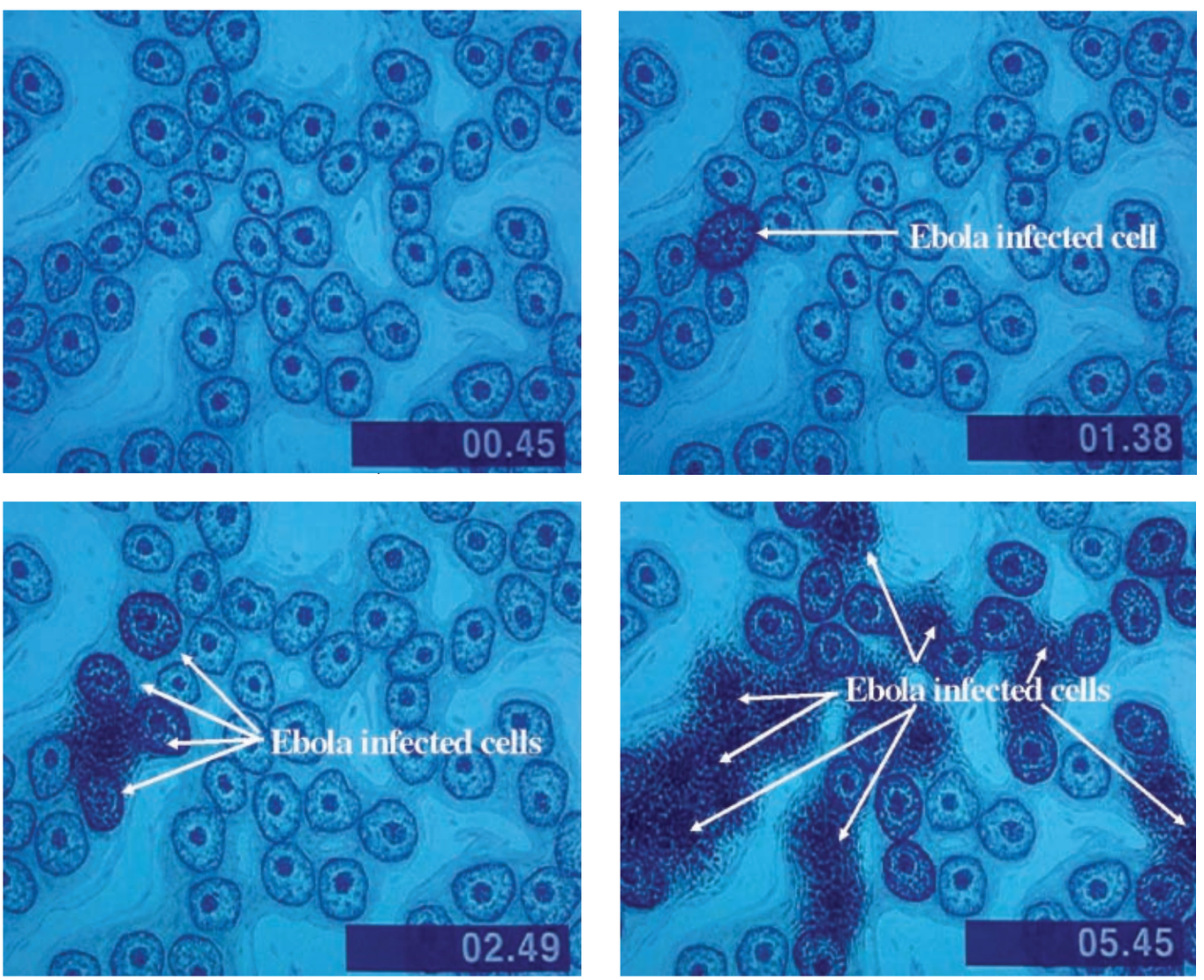
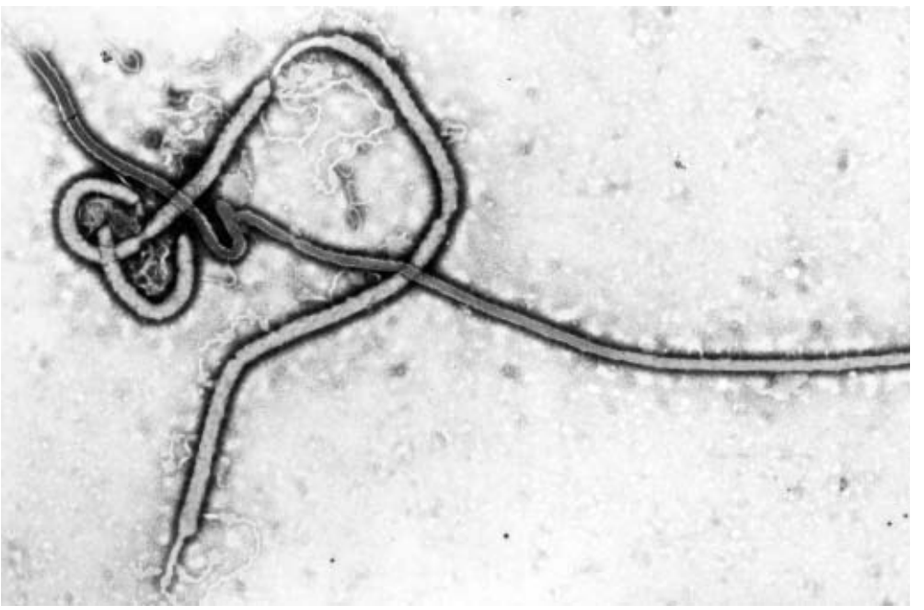
Satellite Detection of Ebola Hemorrhagic Fever Epidemics Trigger Events



Infected liver tissue of patient by Ebola virus. The Ebola virus is transmitted by direct contact with the blood, secretions, organs or other bodily fluids of infected person.

Ebola hemorrhagic fever, named after the Ebola River in Central Africa, first appeared in June 1976, during an outbreak in Nzara and Maridi, Sudan. In September 1976, a separate outbreak was recognized in Yambuku, Democratic Republic of the Congo (DRC). One fatal case was identified in Tandala, DRC in June 1977, followed by another outbreak in Nzara, Sudan, in July 1979. Ebola hemorrhagic fever outbreaks results in a very high

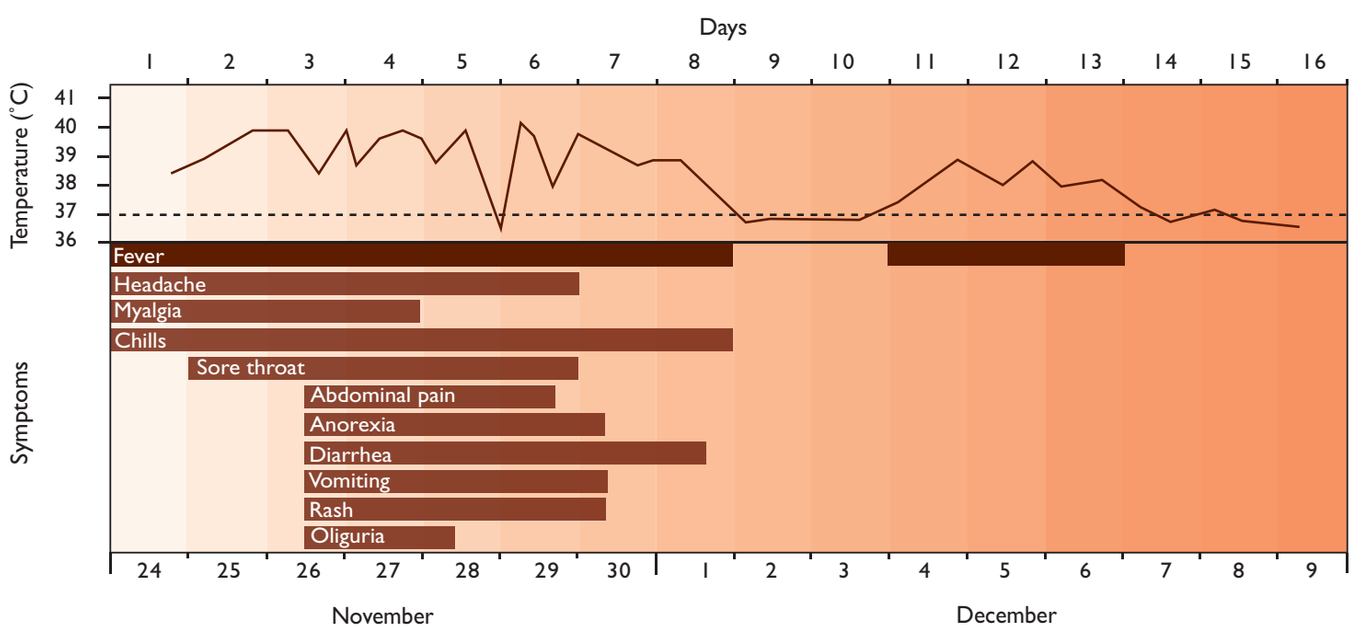


The composition of the Ebola virus. Four distinct subtypes comprise the Ebola virus: Zaire, Côte d'Ivoire, Sudan, and Reston. The first three subtypes have been identified to cause illness in humans. The Reston strain is highly pathogenic for non-human primates, but it has not to date caused illness in humans. This image is from the first isolation and visualization of Ebola virus, 1976. (Micrograph from F. A. Murphy, School of Veterinary Medicine, University of California, Davis.)

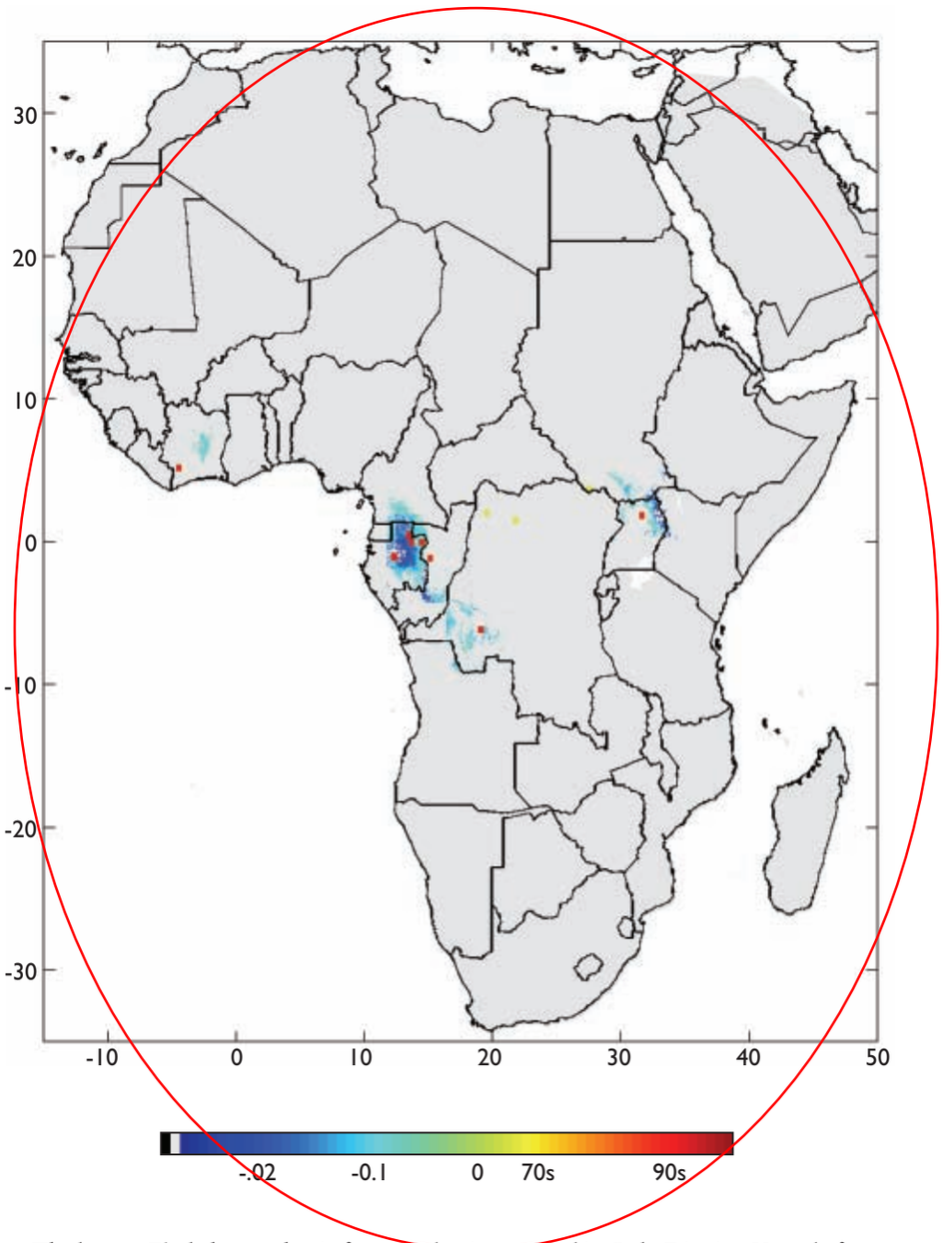
mortality of patients who contract the disease: from 50% to 80% of infected people perish from this highly virulent disease. Death is gruesome, with those afflicted bleeding to death from massive hemorrhaging of organs and capillaries.

The disease was not identified again until the end of 1994, when three outbreaks occurred almost simultaneously in Africa. In October, an outbreak was identified in a chimpanzee community studied by primatologists in Taï, Cote d'Ivoire, with one human infection. The following month, multiple cases were reported in northeast Gabon in the gold panning camps of Mekouka, Andock, and Minkebe. Later that same month, the putative index case of the 1995 Kikwit, DRC, outbreak was exposed through an unknown mechanism while working in a charcoal pit. In Gabon, two additional outbreaks were reported in February and July 1996, respectively, in Mayibout II, a village 40 kilometers south of the original outbreak in the gold panning camps, and a logging camp between Ovan and Koumameyong, near Booue.

Clinical course of Ebola hemorrhagic fever in patient presumably infected during necropsy of infected chimpanzee. Health care workers have been frequently been infected while treating Ebola patients, without correct infection precautions.



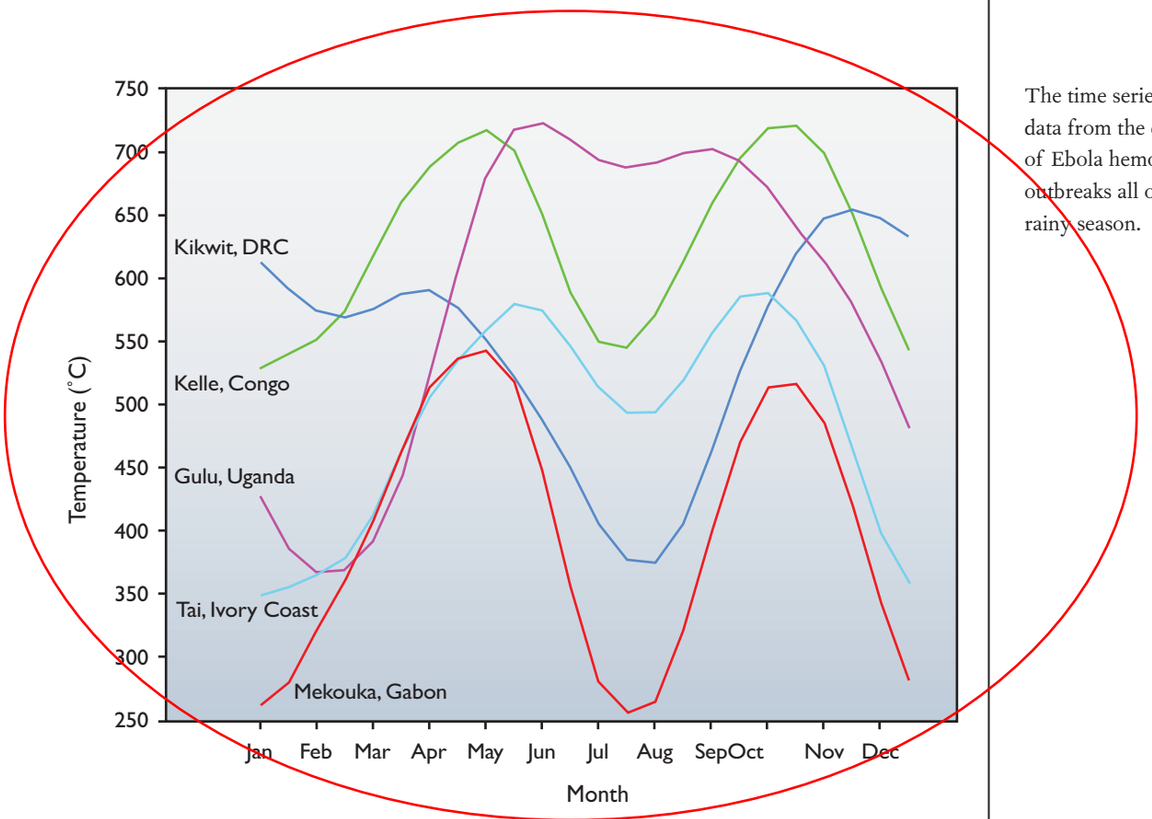
Ebola Hot Zone. Scientific analysis identifies areas where Ebola hemorrhagic fever is endemic. If confirmed by groundwork, this is the 'Ebola Hot Zone'.



The largest Ebola hemorrhagic fever epidemic occurred in Gulu District, Uganda from August 2000 to January 2001. In December 2001, Ebola reappeared in the Ogooue-Ivindo Province, Gabon with extension into Mbomo District, The Republic of the Congo lasting until July 2002.

Of interest is the seasonal context and occasional temporal clustering of Ebola hemorrhagic fever outbreaks. Near simultaneous appearances of Ebola epidemics in Nzara, Sudan and Yambuku, DRC in 1976 occurred within two months of each other in two geographic locations separated by hundreds of kilometers involving two separate viral strains (Sudan and Zaire EBO strains). The outbreaks of Taï, Cote d'Ivoire; Mekouka, Gabon; and Kikwit, DRC in late 1994 also occurred within months of each other in three different geographic regions involving two different viral strains (Cote d'Ivoire and Zaire EBO strains). Fifteen years passed between the 1976 to 1979 and 1994 to 1996 temporal clusters of Ebola cases without identification of additional cases.

Despite extensive field investigations to define the natural history of the Ebola hemorrhagic fever virus, the origin and mechanism of disease transmission, from reservoir to



The time series behavior of the NDVI data from the documented outbreak sites of Ebola hemorrhagic fever. Note the outbreaks all occur toward the end of the rainy season.

humans, remains a mystery. Nevertheless, Ebola hemorrhagic fever and several other infectious diseases, e.g. rift valley fever, cholera, hantavirus, have been studied using satellite data that suggest climatic modulation of incidence. The satellite imagery is used to firstly identify proxy indicators of Ebola risk, and sescondly to characterize areas endemic to this infectious disease.

Normalized difference vegetation index (NDVI) time series data can be used as a proxy for rainfall. These data are derived from measurements made by the AVHRR instruments carried on the NOAA series of meteorological satellites. The NDVI is computed from the red (550 to 700 nanometer) and near infrared (730 to 1100 nanometer) channels of the AVHRR.

The NDVI is sensitive to different types of vegetation showing, for example, changes that take place in the wet and dry seasons. Relevant changes in vegetation over time, derived using a powerful mathematical tool called singular value decomposition, can be used to relate changes in NDVI to documented outbreak sites of Ebola hemorrhagic fever. Landsat data confirms that all Ebola hemorrhagic fever outbreaks occurred in either tropical moist forest or gallery tropical forest in a matrix of savanna. More specifically, these data have enabled analysis of the satellite data identification of the 'Hot Zone' of Ebola hemorrhagic fever in Africa. This is the area where indicates Ebola hemorrhagic fever is endemic, allowing more detailed study of these areas.

The geography of Ebola. All Ebola hemorrhagic fever outbreaks occurred in either tropical moist forest or gallery tropical forest in a matrix of savanna.

While Ebola hemorrhagic fever is one of the glamour diseases at this time, a similar remote sensing protocol is adaptable to examination of other

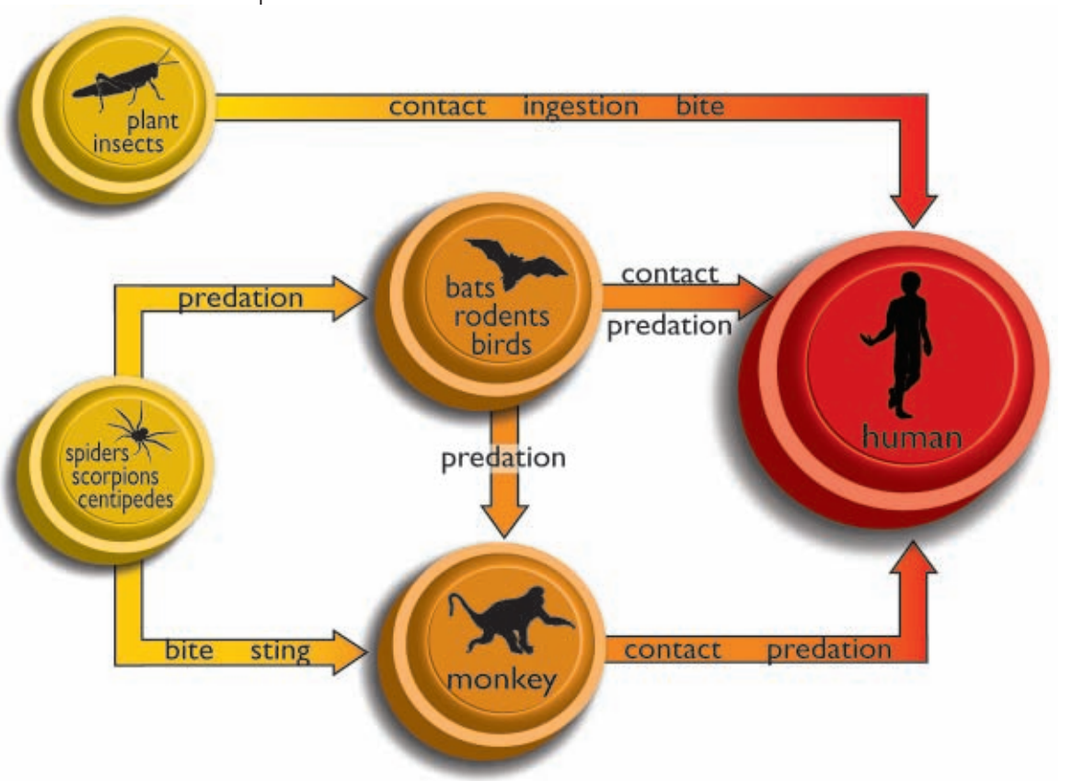


Figure in Progress

The origin and mechanism of disease transmission, from reservoir to humans, remains unknown despite extensive studies.

infectious diseases through the investigation of environmental and climatic links between diseases and satellite data and rainfall, and how these vary in time. This information is important for public health communities in the four phases of preparedness, response, recovery, and mitigation of the epidemic management. The most significant impact of this field of research is the design of remote sensing systems for infectious disease forecasting, which has implications for proactive versus reactive measures of epidemic control.